The offline effects of brain stimulation and music on gait

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Background

Research has demonstrated that music and rhythm significantly influence gait cadence, with faster rhythms correlating to increased walking pace (Leow, 2014). This effect arises because music and rhythm engage the motor system through extensive connections between the brain's auditory and motor regions, particularly activating the Supplementary Motor Area (SMA). The SMA plays a critical role in preparing the timing and sequencing of movements, including the recruitment of motor programs responsible for walking (Weersink, 2020). Studies have shown that heightened SMA activation through rhythmic stimuli not only improves performance on rhythm discrimination tasks (Leow, 2022) but also enhances gait parameters (e.g., step length, velocity) in Parkinson's patients (Kim, 2018).

Building on these findings, transcranial direct current stimulation (tDCS) has emerged as a promising therapeutic tool for movement disorders. This non-invasive technique modulates motor function by applying a weak electrical current to the scalp, altering neuronal excitability in targeted brain areas (Bindman, 1964). When delivered to the SMA, anodal tDCS increases cortical excitability (Nitsche & Paulus, 2000), with effects that can persist beyond the stimulation period. Early work by Bindman et al. (1964) in anesthetized rats demonstrated that direct current stimulation could modify neural activity and cortical excitability for hours post-stimulation. Later research by Nitsche and Paulus (2000) confirmed that prolonged tDCS (several minutes) induces excitability changes lasting over an hour. Notably, while most studies focus on effects during stimulation, Santarnecchi (2014) found that tDCS-induced excitability changes become most significant *after* stimulation ends.

Our tDCS protocol was designed based on three key insights: First, the SMA is specialized for beat processing, with its activity scaling to rhythm clarity (Grahn & Brett, 2007). Second, Parkinson's patients with SMA dysfunction showed an improvement in gait parameters through repetitive transcranial magnetic stimulation (rTMS) of the SMA (Kim, 2018), underscoring its causal role. Third, tDCS over the SMA enhances rhythm discrimination in healthy adults (Leow, 2022), though its impact on walking and gait, especially *offline* (post-stimulation) remains less explored.

Our study investigates how offline tDCS influences not only rhythm perception but also walking synchronization to musical beats and gait performance in healthy participants. Prior work suggests that tDCS effects on rhythm-motor coupling are task-dependent, with more complex interactions emerging during dynamic tasks like walking (Leow, 2022). Focusing on offline effects is particularly novel, as this area remains understudied despite its potential clinical relevance.

In summary, integrating insights from rhythm perception, SMA functionality, and non-invasive brain stimulation offers a promising approach to improving motor function in populations with movement disorders like Parkinson's disease. By modulating SMA excitability, we may enhance motor coordination, facilitate gait initiation, and promote more efficient walking patterns.

Purpose/ Objective

Groove is said to be the quality of music related to the psychological and physiological reactions of listening to music, such as feelings of pleasure and the urge to move. This study assessed the effects of Transcranial Direct Current Stimulation (tDCS) manipulation of the Supplementary

Motor Area (SMA) on ratings of the urge to move, pleasure and familiarity in the presence of low or high-groove music.

We are testing to see if the effects of tDCS will be lasting effects after the stimulation has been removed and if it will still have effects on the participants' gait. There is evidence that supports that tDCS can have lasting effects due to its long term potentiation (LTP)-like plasticity, causing the changes in the synapses to persist long term (Fraise, 2021). While this study was done specifically looking at the visual cortex, it is believed it could have similar effects on the SMA: tDCS has been shown to improve neuroplasticity in patients with cerebral small vessel disease (CSVD), leading to sustained improvements in walking ability and gait. This increased cerebral blood flow caused by tDCS can enhance the blood flow to specific regions such as the SMA. These changes in blood flow have been shown to persist after stimulation, and support improved motor function (Qiaoqiao, 2025).

Our study is unique because not only are we testing the offline (post-stimulation) effects on gait but we are also combining tDCS with personalized rhythmic cues (music 10% faster than the participants baseline cadence) and we are evaluating subjective (groove perception) and objective (gait metrics) outcomes.

Methods

14 healthy undergraduate psychology students from the University of Western Ontario with self-reported normal hearing (10 females, 4 males) participated in this study for course credit. One participant was excluded due to prior knowledge of the research. The study was approved

by the Human Research Ethics Committee at the University of Western Ontario. All participants provided written informed consent.

Baseline walk

Our study is designed for a 2 day period, with baseline, pre- and post-stimulation measurements taken on both days. During the first day of the study, the participant completes the consent form and then completes a "baseline walk", where they walk at their normal pace for eight lengths of the gait mat, with no music stimuli. Previous studies using similar walkways have shown that six walks results in a sufficient number of steps for reliable estimation of gait parameters (Hollman et al., 2010). We then process this walk using the PKMAS software, which is connected to the gait mat, to determine their baseline cadence.

Pre-stimulation walks

MATLAB is then used to select the song files that correspond with 10% faster cadence than their baseline cadence. These songs are then each used as stimuli for 3 different music walks, consisting of 8 lengths of the mat each. The participant was instructed to synchronize their steps to the beat of the music for these music walks, this means corresponding their steps with the basic, underlying pulse throughout the song – what you would tap your foot to.

tDCS stimulation

We then equip the participant with tDCS. To do this we first measured the head to find the SMA, for our electrode placement. The SMA location is located by using the EEG international system (Leow, 2022). We measure from inion to nasion and marking the halfway point, then measure

from tragus to tragus of each ear and find the intersection between each point. The anodal electrode was placed ~2 cm ahead of the intersection point, overtop the SMA. The electrodes were placed under a sponge that is soaked in saline solution, acting as a salt bridge to ensure connection of the electrodes to the skin .

Depending on if the participant is completing their anodal day of the study or their sham day of the study, the tDCS was set to 2mA for 20 minutes of stimulation or paused at 2mA and set back to 0mA for sham (control) session.

Demographic Survey

Participants completed a comprehensive demographic questionnaire assessing their musical background and movement experience. This included detailed questions about: (1) current and past instrumental practice (including duration and frequency), (2) formal music training and theory instruction (specifying years of study and certification levels, if applicable), (3) pedagogical methods encountered during musical education, and (4) dance experience. These measures allowed us to account for potential confounding effects of prior rhythm-related training on participants' groove perception and movement synchronization abilities.

Groove Survey

The participant then completed the groove survey consisting of 40 20-second clips of unfamiliar songs (to minimize memory/associative biases) to the general demographic of current Western University Students. Half were researcher-classified as groovy and half as non-groovy, based on subjective judgments of movement-inducing qualities per Madison's (2006) definition; how

much music evokes the desire to move. This binary categorization reflected our operationalization of groove as music's ability to elicit a kinesthetic response. Audio editing (via Audacity) removed all lyrical content to isolate rhythmic/melodic characteristics.

For each 20s clip, participants were asked to respond to three questions on a scale of 0-100. To assess groove perception, we selected three items from an Experience of Groove Questionnaire (adapted from Senn et al., 2020); two questions about the 'urge to move' feeling: “This music evokes the sensation of wanting to move some part of my body (M1)”, “This music is good for dancing (M2)”; and one question about pleasure: “I like listening to this music (P2)” (Table 1).

Post-stimulation walks

After the survey, the participant completed another silent walk, where they walk at their normal pace for 8 lengths of the gait mat, with no music stimuli. They also completed another 3 walks (each consisting of 8 lengths of the gait mat) with the 10% faster music stimuli, consisting of 3 different songs from the pre-stimulation walks. The participant is again asked to synchronize their steps to the beat of the music. The order of these post-stimulation walks (silent vs music) is counterbalanced.

Study Day 2

During the second day of the study, the participants repeated the exact same study design as day 1; however, they received the opposite treatment than what they received during the first session (anodal or sham) and the demographic survey was omitted. As in the first study the order of the walks, post-tDCS stimulation is counterbalanced.

All walks are processed using the PKMAS software to determine the participants cadence.

Results

Statistical analyses were conducted in JASP using repeated-measures ANOVAs to examine within-subject effects across experimental conditions. This approach was selected to account for individual differences while testing how groove ratings (M1, M2, P2) varied with stimulation (tDCS) and cue (music). We also assessed how velocity, stride length and cadence varied with stimulation and music.

Demographics

Out of the 13 participants (9 female, 4 male), 79% (n=11) had instrumental training (mean 8±4.5 years), though only 14% (n=2) were currently practicing. Participants averaged 4 (range: 0-10+) years of formal music training and 2 (range: 0-5) years of theory instruction, with most people's training occurring through private lessons. Notably, 86% (n=12) reported dance experience, suggesting prior movement-music coordination experience (Table 2).

Music ranking measures

Preliminary analysis revealed mixed neuromodulatory effects of tDCS on music perception and gait parameters (Figure 1; Table 3). For music ranking measures, while no significant differences emerged in general liking (P2) between stimulation conditions (all $p > 0.44$), anodal tDCS produced groove-level-dependent modulation: it significantly enhanced danceability ratings (M2) for low-groove songs ($t = 2.66$, $p = 0.021$) while showing a non-significant reduction in movement motivation (M1) for high-groove stimuli ($t = -0.73$, $p = 0.48$).

Cadence

The ANOVA test (Table 6) for cadence revealed a strong main effect of tDCS stimulation ($p < 0.001$, $\eta^2 = 0.448$) indicating that stimulation type (anodal vs. sham) had a strong effect on the dependent variable. In contrast, the main effect of cue (silent vs. music) was not significant ($p = 0.115$, $\eta^2 = 0.028$), suggesting that the type of auditory cue did not independently influence outcomes. Stim×Cue also had a significant interaction ($p = 0.005$, $\eta^2 = 0.066$), indicating that the effect of stimulation varied depending on the cue condition.

Post-hoc tests (Table 6) demonstrated robust anodal tDCS effects in silent conditions (Sham+Silent: $p < 0.001$; Sham+Music: $p < 0.001$), which were weakened when combined with music (Anodal+Music vs. Anodal+Silent: $p = 0.010$). Though music alone showed no main effect ($p = 0.115$), the significant Stim×Cue interaction ($p = 0.005$) revealed its capacity to modulate tDCS efficacy. Specifically, Anodal+Music produced weaker benefits than Anodal+Silent while still outperforming Sham+Music ($p = 0.010$), suggesting partial but incomplete override of stimulation effects by auditory cues (Figure 2a).

Velocity

While we found no overall effect of tDCS on gait velocity ($p = 0.748$), our ANOVA (Table 4) showed a significant stimulation×cue interaction ($p=0.04$, $\eta^2=0.18$), with a near-significant cue effect ($p=0.06$, $\eta^2=0.17$). A post hoc test (Table 7) was done for this significant finding, which showed that none of the comparisons reached significance, only trending differences (e.g., Anodal+Music vs. Anodal+Silent: $p = 0.113$), indicating these effects are weaker than music's dominant role (Figure 2b).

Stride length

Stride length measures showed no significance for stimulation or cue (stim: $p=0.8$, $\eta^2=0.002$, cue: $p=0.07$, $\eta^2=0.03$), while the stimulation×cue interaction is approaching significance ($p=0.07$, $\eta^2=0.03$). A post hoc test (Table 5) for the stimulation×cue interaction suggests no specific pairwise comparison drives this effect strongly enough to be significant after multiple comparison correction. Since the ANOVA (Table 8)wasn't significant and the post hoc tests are far from significant, we can assume the data doesn't provide strong enough evidence for a real effect (Figure 2c).

Confounding variables

Although our participants had musical training, we did not formally assess its influence on outcomes. Thus, while the observed effects of SMA stimulation on movement motivation might reflect this cohort's musical engagement, gait improvements appeared driven primarily by auditory cues rather than stimulation. Future work should test whether musicality moderates stimulation effects.

Discussion

Music ranking measures

Anodal tDCS largely and significantly enhanced danceability ratings for low-groove songs, aligning with SMA's role in subjective rhythm appraisal (Stupacher et al., 2013). We may see this if the anodal tDCS lowered the threshold for SMA rhythm perception, making participants more sensitive to subtle rhythmic cues. This aligns with findings from Grahn (2012) where

neuroimaging shows SMA activity scales with beat ambiguity, suggesting it compensates for weak rhythms which can be found in less groovy songs. Additionally, it may not have had an effect, or had this small negative effect on the high-groove songs because high-groove songs drive strong motor responses due to their high rhythmic predictability (Janata et al., 2012). tDCS may not further enhance, and may potentially diminish these responses because the system is already maximized. Leow et al. (2018) propose that in Parkinson's disease patients – where basal ganglia dysfunction impairs endogenous motor timing – the combination of high-groove music and SMA tDCS may produce additive therapeutic effects. This contrasts with healthy populations, where intact subcortical networks may find the combination of stimulation and cue redundant and unnecessary or even detrimental.

There was also a dissociation found between subjective vs. objective effects. SMA tDCS modulated movement motivation (groove survey “urge to move” ratings) but not gait, suggesting separable circuits for intention vs. execution. This could be confounding effects from the pre-SMA, right next to the SMA, which has been found to activate reward areas of the brain. Anodal tDCS may have diffused to this region, amplifying subjective "urge to move" (Matthews, 2020).

Seeing a significant difference between high groove and low groove songs for the urge to move ratings (M1 & M2) makes sense because high levels of groove have been found to improve gait by modulating an individual’s affective state. In particular, high-groove music elicits higher arousal as well as a positive affective state (Janata et al., 2012). Similarly, the result showing that there was a significant difference in “wanting to dance” to high groove vs low groove songs in

the anodal condition is supported by evidence that shows even at rest, high-groove music regulates excitability of the motor system more than low-groove music (Stupacher et al., 2013).

Cadence

Music cues significantly altered cadence, while tDCS alone showed no offline effects. Post-hoc analyses confirmed this pattern: both Sham+Music (t = -4.636, p = 0.001) and Anodal+Music (t = -5.133, $p < 0.001$) conditions increased cadence compared to their silent counterparts, with Sham+Music outperforming Anodal+Silent (t = -4.279, p = 0.001). Critically, Anodal+Music provided no added benefit over Sham+Music (t = 0.637, p = 0.589), as well the comparison of the silent groups (Anodal+Silent vs. Sham+Silent: t = 1.087, p = 0.589) had no measurable impact. These results suggest that rhythmic auditory cues dominate gait modulation in healthy individuals, likely by engaging subcortical locomotor networks (basal ganglia, brainstem) while bypassing SMA-dependent pathways. This aligns with evidence from spinalized animal models, where rhythmic cues directly synchronized spinal locomotor circuits without cortical input (Lavrov et al., 2015). Thus, while SMA stimulation may require longer durations or clinical populations to exert effects, music-driven entrainment appears sufficient to override cortical modulation in intact nervous systems.

Velocity

These velocity results suggest that while tDCS may subtly enhance music's influence on gait speed, we cannot definitively attribute this to specific condition comparisons after multiple comparison correction. The interaction effect - though statistically significant - appears driven by small, distributed differences across conditions without distinct differences between particular

groups. This pattern aligns with our broader finding that music cues dominate gait modulation, with tDCS exerting more subtle, context-dependent effects.

Stride Length

These results suggest that stride length - unlike other gait parameters we measured - appears relatively resistant to both tDCS and musical cueing interventions under our experimental conditions. The borderline effect of stimulation x cue, while not statistically significant by conventional thresholds, may hint at a subtle relationship worth exploring in future studies with larger samples. However, the absence of significant pairwise contrasts and the negligible effect sizes (all $\eta^2<0.03$) indicate that even if real effects exist, they are likely too small to be clinically meaningful or our sample size is not large enough to support these effects.

Conclusion

While gait parameters were predominantly cue-driven, the significant interaction between stimulation and cue for velocity suggests that tDCS may selectively modulate certain aspects of walking in a cue-dependent manner. In contrast, danceability perceptions were more broadly enhanced by anodal tDCS, particularly for low-groove music. tDCS did alter how people felt about the music, as scored by the “urge to move” questions. The music perception shows the SMA’s role in subjective rhythm processing (how we experience musical "groove"); however, walking patterns did not change. Only the auditory cues (music) affected gait, suggesting that stimulation of the SMA might not have offline effects on gait.

The dissociation between the effects on subjective musical rating (where tDCS showed significant effects) versus objective gait measures (where only auditory cues had significant impact) suggests two key insights: First, SMA stimulation may preferentially influence higher-order movement intention circuits rather than basic locomotor pathways in healthy, musically-trained individuals. Second, the fact that walking patterns remained more responsive to musical rhythms than to tDCS supports clinical experience: rhythmic sound cues typically help gait rehabilitation more than brain stimulation alone (Leow, 2014; Qiaoqiao, 2025).

Several limitations warrant consideration. The small sample size (N=13) may have underpowered detection of tDCS interactions with gait, particularly given the effects of participants' pre-existing musical training (86% dancers and 79% musically trained, average 8 years of experience). Additionally, the 20-minute stimulation protocol, while sufficient to induce LTP-like plasticity in sensory cortices (Nitsche & Paulus, 2000), might require longer duration or repeated sessions to drive lasting SMA-mediated gait changes.

Musical training was not included as a covariate in analyses to account for pre-existing auditory-motor expertise, and high musical training may mask tDCS effects. This is significant given evidence that musicians exhibit neuroplastic adaptations that may mask tDCS effects, including enhanced SMA-auditory connectivity (Zatorre, 2007). Such pre-existing auditory-motor expertise likely creates a "ceiling effect," wherein trained individuals have less room for tDCS-induced improvement due to already-optimized networks (Matthews, 2020). Future research should stratify samples by training duration (e.g., >5 vs. <2 years) and measure baseline auditory-motor connectivity (via resting-state fMRI) to better isolate tDCS effects.

Future studies should combine tDCS with multimodal imaging to explore current diffusion patterns and their behavioral consequences. Simultaneous fMRI during stimulation could track both slow changes in subcortical networks (e.g., putamen) and fast auditory-motor processing in the brainstem. This approach would clarify whether tDCS must be precisely targeted to SMA proper versus pre-SMA to influence gait. We could also look at the change of activation in different brain areas (ie. motor cortex, auditory cortex, motor circuits, etc.) before and after tDCS stimulation of the SMA. In clinical populations, this could identify which patients' residual connectivity patterns predict tDCS responsiveness.

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Tables

Table 1. Participant Demographic Information

Table 1. Groove Questionnaire

Category	Question
Demographics	Age
	Gender
	Which hand do you write with?
	What is the highest level of education you have completed or are currently completing?
	What is your first language?
	What is your ethnicity?
	How is your general health?
	Do you have any hearing impairments?
	Do you have any vision impairments?
Music Preferences	Select the music genres you normally listen to.
	How familiar is the piece of music to you? (1 = Never heard it before; 100 = Know this song so well that I can predict what happens next)
	How much does this piece of music make you want to move? (1 = Would definitely not move to this; 100 = Would move a lot to this)
	How much do you enjoy listening to this piece of music? (1 = Strongly dislike this song; 100 = Strongly enjoy this song)
	How strong is the beat in this piece of music to you? (1 = Very weak; 100 = Very strong)
Dancing Experience	Rank your level of experience with dancing.
Music Experience	Have you ever played a musical instrument? If yes, which and for how long?
	Are you currently practicing music? If yes, how many hours a week do you practice?
	What type of musical training did you receive?
Music Training History	I engaged in regular, daily practice of a musical instrument (including voice) for _ years.
	At the peak of my interest, I practiced my primary instrument for _ hours per day.
	I have had formal training in music theory for _ years.
	I have had _ years of formal training on a musical instrument (including voice) during my lifetime.
	I can play _ musical instruments.
Self-Assessment	I have never been complimented for my talents as a musical performer.
	I would not consider myself a musician.

Note. descriptive statistics from the demographic survey of study participants.

Table 2. Demographic Survey Results

Demographics	Response
Gender	Female: 10, Male: 4
Played an Instrument	Yes: 11, No: 3
Average Years of Experience	8 (instrument), 7.5 (daily practice)
Currently Practicing	Yes: 2, No: 12
Training Background	Mostly private lessons (some self-taught/high school)
Formal Training Duration	4 years (average)
Music Theory Training	2 years (average)
Dance Experience	Yes: 12, No: 2

Note. Summary of survey responses including age, sex, and other relevant participant characteristics.

Table 3. ANOVA Results for M1, M2, and P2 Conditions

M1:

Paired Samples T-Test

Measure 1		Measure 2	t	df	p	Cohen's d	SE Cohen's d
High_Anodal	–	High_Sham	−0.729	12	0.480	−0.202	0.130
Low_Anodal	–	Low_Sham	0.248	12	0.808	0.069	0.138

Note. Student's t-test.

M2:

Paired Samples T-Test

Measure 1		Measure 2	t	df	p	Cohen's d	SE Cohen's d
High_Anodal	–	High_Sham	0.367	12	0.720	0.102	0.128
Low_Anodal	–	Low_Sham	2.663	12	0.021	0.738	0.080

Note. Student's t-test.

P2:

Paired Samples T-Test

Measure 1		Measure 2	t	df	p	Cohen's d	SE Cohen's d
High_Anodal	–	High_Sham	0.687	12	0.505	0.191	0.091
Low_Anodal	–	Low_Sham	0.797	12	0.441	0.221	0.116

Note. Student's t-test.

Note. Analysis of variance comparing M1, M2, and P2 conditions across selected dependent variables.

Table 4. Cadence: ANOVA and Post Hoc Results

Repeated Measures ANOVA

Within Subjects Effects

Cases	Sum of Squares	df	Mean Square	F	p	η^2
Stim	187.302	1	187.302	19.712	< .001	0.448
Residuals	114.024	12	9.502			
Cue	11.771	1	11.771	2.889	0.115	0.028
Residuals	48.896	12	4.075			
Stim ✻ Cue	27.528	1	27.528	11.652	0.005	0.066
Residuals	28.351	12	2.363			

Note. Type III Sum of Squares

Post Hoc Comparisons - Stim ✻ Cue

		Mean Difference	SE	t	p_{holm}
Sham, Silent	Anodal, Silent	−5.251	0.955	−5.496	< .001
	Sham, Music	−0.504	0.704	−0.716	0.482
	Anodal, Music	−2.844	1.022	−2.783	0.034
Anodal, Silent	Sham, Music	4.747	1.022	4.645	< .001
	Anodal, Music	2.407	0.704	3.420	0.010
Sham, Music	Anodal, Music	−2.341	0.955	−2.450	0.050

Note. P-value adjusted for comparing a family of 6

Note. Statistical results for cadence comparisons, including post hoc pairwise analyses.

Table 4. Velocity: ANOVA and Post Hoc Results

Repeated Measures ANOVA

Within Subjects Effects

Cases	Sum of Squares	df	Mean Square	F	p	η^2
Stim	5.533	1	5.533	0.109	0.748	0.004
Residuals	559.349	11	50.850			
Cue	258.230	1	258.230	4.506	0.057	0.169
Residuals	630.335	11	57.303			
Stim ✻ Cue	26.024	1	26.024	5.678	0.036	0.017
Residuals	50.419	11	4.584			

Note. Type III Sum of Squares

Post Hoc Tests

Post Hoc Comparisons - Stim ✻ Cue

		Mean Difference	SE	t	p_{holm}
Sham, Music	Anodal, Music	−0.794	2.149	−0.369	0.748
	Sham, Silent	3.166	2.271	1.394	0.748
	Anodal, Silent	5.318	3.002	1.771	0.452
Anodal, Music	Sham, Silent	3.960	3.002	1.319	0.748
	Anodal, Silent	6.112	2.271	2.691	0.113
Sham, Silent	Anodal, Silent	2.152	2.149	1.001	0.748

Note. P-value adjusted for comparing a family of 6

Note. Analysis of velocity data, including between-group comparisons and post hoc results.

Table 8. Step Length: ANOVA and Post Hoc Results

Repeated Measures ANOVA

Within Subjects Effects

Cases	Sum of Squares	df	Mean Square	F	p	η^2
Stim	0.996	1	0.996	0.065	0.803	0.002
Residuals	168.545	11	15.322			
Cue	8.875	1	8.875	0.369	0.556	0.018
Residuals	264.605	11	24.055			
Stim ✻ Cue	14.046	1	14.046	3.900	0.074	0.028
Residuals	39.619	11	3.602			

Note. Type III Sum of Squares

Post Hoc Tests

Post Hoc Comparisons - Stim ✻ Cue

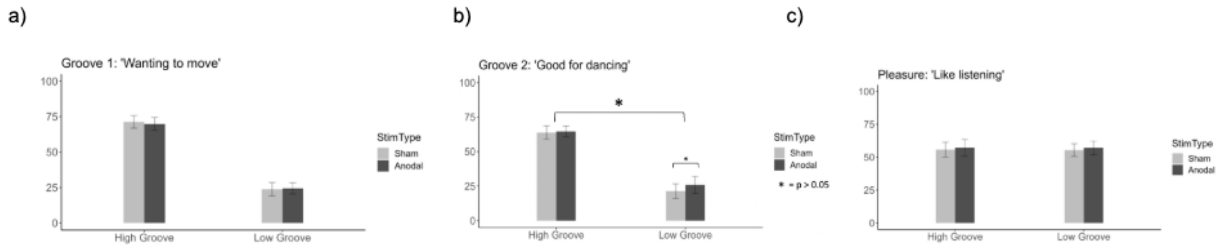
		Mean Difference	SE	t	p_{holm}
Sham, Silent	Anodal, Silent	0.794	1.256	0.632	1.000
	Sham, Music	0.222	1.518	0.146	1.000
	Anodal, Music	−1.148	1.811	−0.634	1.000
Anodal, Silent	Sham, Music	−0.572	1.811	−0.316	1.000
	Anodal, Music	−1.942	1.518	−1.279	1.000
Sham, Music	Anodal, Music	−1.370	1.256	−1.091	1.000

Note. P-value adjusted for comparing a family of 6

Note. ANOVA and post hoc comparisons for step length across conditions.

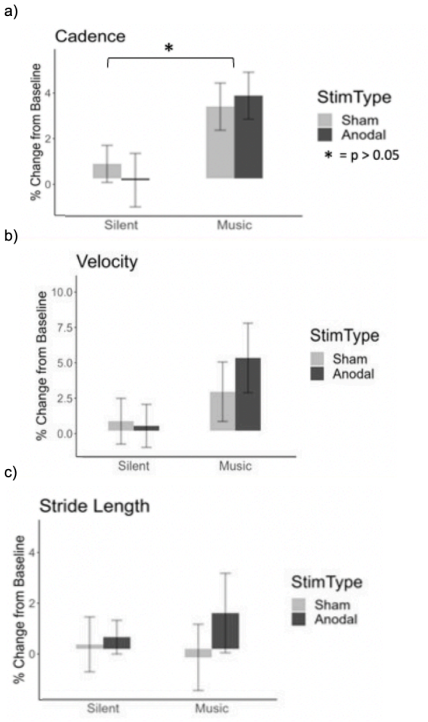
Figures

Figure 1. Comparison of M1, M2, and P2 Conditions



Note. Visual representation of results across M1, M2, and P2 experimental conditions.

Figure 2. Cadence, Velocity, and Step Length Across Conditions



Note. Bar graphs or line charts showing differences in cadence, velocity, and stride length for each condition.